Forest Evaluation Method Using Integrated SI Models
－A Case Study in Urban Forest in Nagoya, Japan

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Abstract: In recent years, a variety of suitability index (SI) models for endangered species have been developed in Japan. These models have been used to assess Satoyama, and to construct a biodiversity potential map that shows the suitable habitat areas for individual endangered species. However, few studies have developed a forest evaluation method that combines multiple SI models. In the present study, we developed a forest evaluation method, by combining integrated SI models for *Luciola parvula*, *Apodemus speciosus*, and *Accipiter gentilis*. We subsequently applied these SI models as a case study in 4 forest sites of the Nagoya University campus, Nagoya City, Japan. The 3 selected species are representative endangered species of insects, small mammals, and raptors respectively because these species play a significant role in the forest ecosystem. We concluded that the final total environmental quality score of the "paddy fields site" was the higher than that of the other 3 sites. Further studies to enhance each SI model, and improve the selection and integration of multiple SI models for development of a forest evaluation method, are required.

Keywords: *Habitat Evaluation Procedure, Suitability Index Model, Forest Ecosystem, Satoyama*

1. INTRODUCTION

The habitat evaluation procedure (HEP) that was developed in the USA has been paid attention as an environmental assessment method in Japan (Tanaka 2008). A variety of suitability index (SI) models used in HEP have been developed (Kuki and Tanaka 2006) to evaluate the quality of each indispensable condition for the target species. The SI score indicates the habitat quality, and is calculated for the range 0–1.0 by applying collected data to the SI model. The habitat suitability index (HSI) score that is also shown for the range 0–1.0 and indicates synthetic habitat quality score is generally computed by using the geometric average or arithmetical mean of all SI scores.

SI models have also been utilized in various fields such as to assess Satoyama (Ueno et al. 2011), and construct a biodiversity potential map that shows the suitable habitat areas for individual endangered species (e.g., Aichi Prefecture 2010; Ministry of Environment 2005; Noyori et al. 2012; Sato et al. 2013). Ueno et al. (2011) used the SI model for *Apodemus speciosus* (the large Japanese field mouse), to assess the quality of Satoyama. Previous studies regarding biodiversity potential maps have visualized the potential endangered and threatened species habitat areas, and compared these with the actual distribution of the target species.

However, few studies have constructed a forest evaluation method that combines multiple SI models. In the present study, we developed a forest assessment method by combining integrated SI models for the indicator species *Luciola parvula* (firefly), *Apodemus speciosus* (large Japanese field mouse), and *Accipiter gentilis* (northern goshawk). We subsequently applied those SI models as a case study in 4 forest sites of Nagoya University campus. Nagoya University is located in Nagoya city, Aichi Prefecture, between Tokyo and Osaka. The average temperature is approximately 27.8 °C in August and 4.5 °C in January, and the average humidity during the summer is >70% (Nagoya Local Meteorological Observatory, 2014).

2. METHODOLOGY

2.1 Research Flow

The research flow of this study is shown in Figure 1. Firstly, we selected 3 species for assessment of the forest ecosystem. Secondly, we developed SI models for *Luciola parvula* (firefly), for which there were no existing SI models. Thirdly, we conducted field surveys at Nagoya University to collect data for developing the SI models. Finally, we applied those SI models to 4 forest sites in Nagoya University campus as a case study

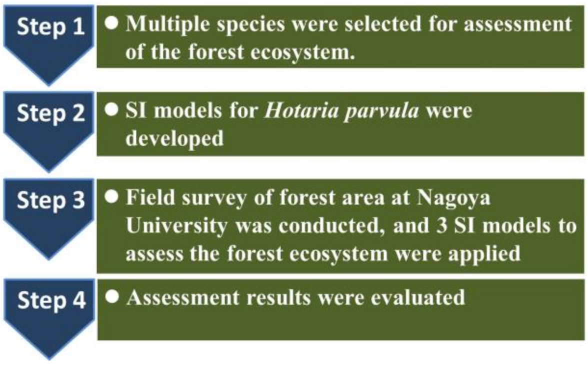

Figure 1 Research flow

2.2 Selection of Multiple Species for Assessment of the Forest Ecosystem

To develop an assessment method for the forest ecosystem, we selected *Apodemus speciosus*, *Accipiter gentilis*, and *Hotaria parvula* as indicator species for small mammals, raptors and insects, respectively (Figure 2). The SI models for *Apodemus speciosus* (Ueno et al. 2011) and *Accipiter gentilis* (Higuchi et al. 2009) were developed previously (Table 1), but there were no existing SI models for *Hotaria parvula*. Therefore, we developed SI models for *Hotaria parvula*, based on the data collected during field surveys of Nagoya University campus, and information obtained from interviews with conservation group members and biological experts during 2011 and 2012.

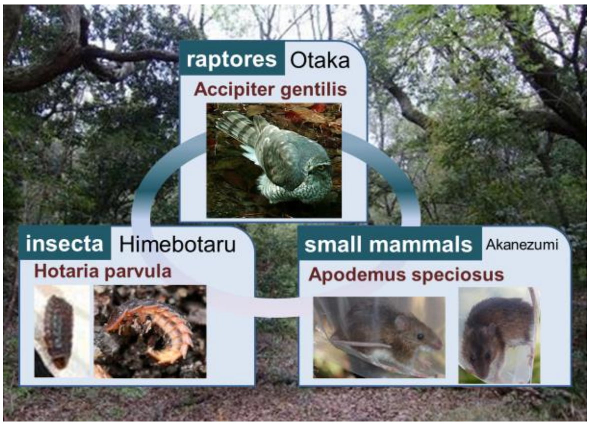

Figure 2 Indicator species for assessment of the forest ecosystem

Table 1 SI models, HSI formulation, and indispensable conditions for *Accipiter gentilis* and *Apodemus speciosus*

SI model	*Accipiter gentilis* (Noyori et al. 2012)	*Apodemus speciosus* (Ueno et al. 2011)
HSI Score Formulation	$HSI = \frac{(SI_1 \times SI_2 \times SI_3 \times SI_4)^{\frac{1}{4}} + 2SI_5}{3}$	$HSI = \frac{SI_1 + SI_2 + SI_3 + SI_4}{4}$
Indispensable conditions	SI_1: Type of wood	SI_1: Number of holes in ground
	SI_2: Average height of wood	SI_2: Canopy
	SI_3: Density of trees	SI_3: Number of tall trees
	SI_4: Forest area	SI_4: Soil hardness
	SI_5: Food condition	–

2.3 Development of SI Models for *Hotaria parvula* (firefly)

We conducted field trap surveys at Nagoya University campus in November 2011 and November 2012. Figure 3 shows the field survey sites at Nagoya University campus. We set a total of 370 traps containing a piece of squid in each film case, as bait for *Hotaria parvula* larvae. At each trap point, we also collected data regarding 4 habitat conditions—forest cover ratio, soil moisture content, cover ratio of fallen leaves, and angle of inclination—for developing the SI models. We selected these 4 habitat conditions based on published literature reports regarding *Hotaria parvula*, and information obtained from interviews with conservation group members and biological experts in Nagoya. As a result of our field trap surveys, we captured >178 *Hotaria parvula* larvae in 103 traps (Table 2). We subsequently developed 4 SI models (Cover ratio of fallen leaves, Soil moisture content, Forest cover ratio, Angle of inclination: Figure 4) based on the data collected and information obtained from interview surveys to biologists and NGO members who are members of the conservation of the *Hotaria parvula* in Aichi region (Ito and Hayashi 2013).

Hotaria parvula larvae live on the undersides of leaves and hide during the daytime, and therefore we developed an SI model for the “Cover ratio of fallen leaves” based on the data collected. The larvae require a small amount of moisture to live in the forest, and therefore we constructed an SI model for the “soil moisture content.” We constructed the SI model for the “forest cover ratio,” because *Hotaria parvula* larvae need sufficient forest cover to maintain an adequate temperature. We constructed an SI model for the “Angle of inclination” based on our field survey data, because *Hotaria parvula* larvae show a preference for sloping land. We also verified that none of the collected data for developing SI models showed collinearity. However, it is necessary to improve these SI models to increase accuracy because these are prototype models.

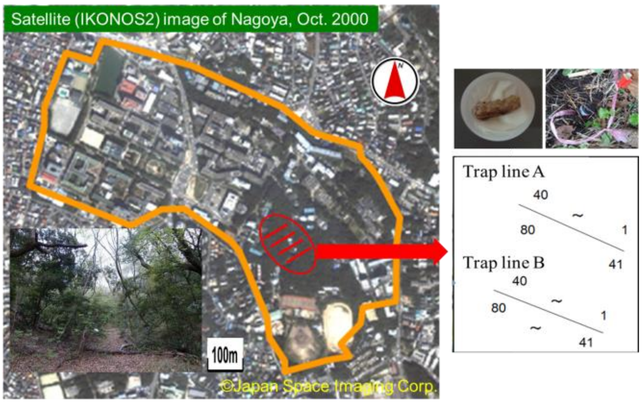

Figure 3 Field survey sites

Table 2 Results of field survey

Date	Traps	No. of Capture points	Rate of captures (%)
Dec, 2011	160	35	21.9%
Dec, 2012	210	68	32.4%
Total	370	103	27.8%

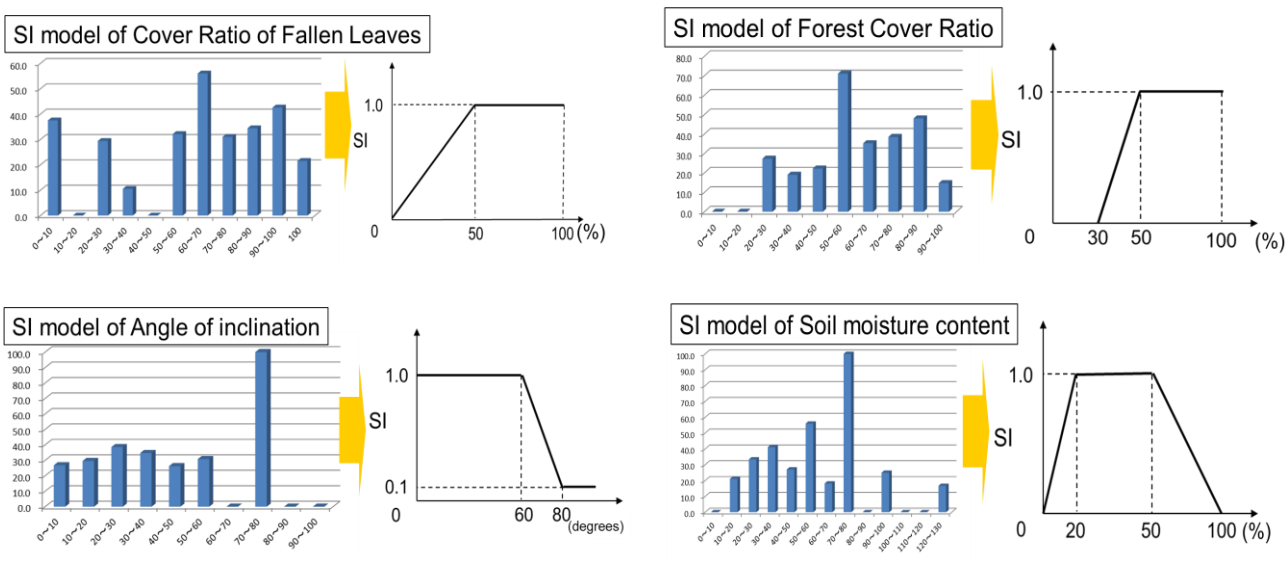

Figure 4 Collected Data and Developed SI models for *Hotaria parvula*

2.4 Collection of Field Survey Data

In 2011 and 2012, we set up a quadrat in each of 4 forest sites (Mizujunkan, Ecotopia, Noyori, and Paddy field) at Nagoya University campus (Figure 5). We subsequently conducted field surveys to collect data related to each indispensable condition from each quadrat, and determined the representative score of each forest site by calculating the averages of the data that was obtained from the field survey and applied these to each SI model.

The selected forest areas consisted of secondary forest. The Paddy field site was located near paddy field test area of the Nagoya University Agricultural Department.

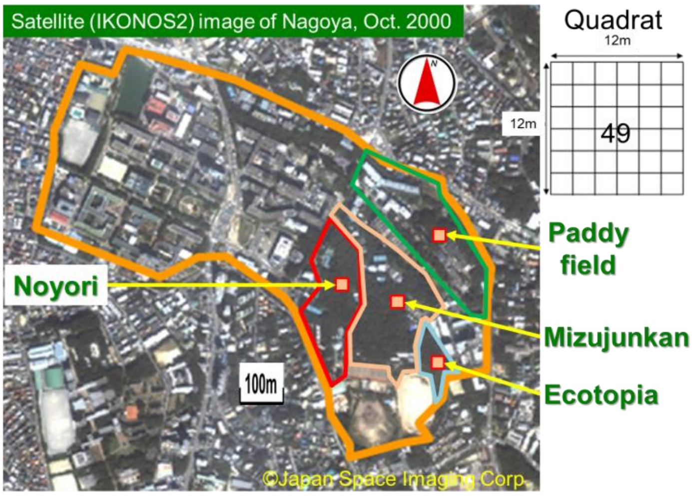

Figure 5 Field survey sites for data collection

3. RESULTS AND DISCUSSION

Firstly, we calculated the scores of the 4 SI models for each of the 3 targeted species in each of the 4 sites by using the field survey results (Table 3). With the exception of "soil moisture content," the scores for *Hotaria parvula* larvae were 1.0 (most suitable); the HSI score for the Noyori forest area was 1.0 (most suitable), whereas the score of the other 3 sites were 0.93. Thus, these sites were suitable habitats for *Hotaria parvula* larvae. On the other hand, the SI scores for "height of trees" at the Mizujunkan and Ecotopia sites were not sufficiently high for *Accipiter gentilis*. Further, the scores for "food condition" at the Mizujunkan, Ecotopia, and Noyori sites were low. Thus, with the exception of the Paddy field site, the HSI scores were low. The SI scores for "number of holes" were low for *Apodemus speciosus* 0.42, 0.42, and 0.30 at the Mizujunkan, Noyori, and Paddy field sites, respectively. The SI scores for "canopy" were also relatively low (0.61 and 0.49) at the Ecotopia and Noyori sites. Therefore, the HSI scores for *Apodemus speciosus* at each of the 4 sites were slightly lower than those for *Hotaria parvula*, but higher than those except Paddy field site for *Accipiter gentilis*.

To calculate the synthetic score for each forest site, we averaged the HSI scores of the 3 species at each site. We determined the highest final score of 0.87 for the Paddy field site, and final scores of 0.68 or 0.67 for the other 3 sites. In addition, we indicated that there are many improvement points such as lower tree height at the Mizujunkan and Ecotopia, lack of forest canopy cover at the Noyori, and small forest area at the Ecotopia by applying all SI models of 3 species. Our results show that the application of integrated SI models as a case study in 4 forest sites at Nagoya University campus clearly identify factors that cause a decrease in forest quality.

Table 3 Assessment results for each forest area

Forest Area		Mizujunkan					Ecotopia					Noyori					Paddy field				
Hotaria parvula	HSI	0.93					0.93					1.00					0.93				
	SI	1.0	0.71	1.0	1.0		1.0	0.71	1.0	1.0		1.0	1.0	1.0	1.0		1.0	0.71	1.0	1.0	
	items	Forest cover ratio	Soil moisture content	Cover ratio of fallen leaves	Angle of inclination		Forest cover ratio	Soil moisture content	Cover ratio of fallen leaves	Angle of inclination		Forest cover ratio	Soil moisture content	Cover ratio of fallen leaves	Angle of inclination		Forest cover ratio	Soil moisture content	Cover ratio of fallen leaves	Angle of inclination	
Accipiter gentilis	HSI	0.39					0.30					0.38					1.0				
	SI	1.0	0.34	1.0	1.0	0.20	1.0	0.24	1.0	0.24	0.20	0.36	1.0	1.0	0.81	0.20	1.0	1.0	1.0	1.0	1.0
	items	Type of wood	Height	Density of trees	Forest area	Food condition (Open land)	Type of wood	Height	Density of trees	Forest area	Food condition (Open land)	Type of wood	Height	Density of trees	Forest area	Food condition (Open land)	Type of wood	Height	Density of trees	Forest area	Food condition (Open land)
Apodemus speciosus	HSI	0.71					0.78					0.62					0.68				
	SI	0.42	0.87	0.69	1.0		0.75	0.61	0.80	1.0		0.42	0.49	0.72	1.0		0.30	0.70	1.0	1.0	
	items	Number of holes	Canopy	Number of tall trees	Soil hardness		Number of holes	Canopy	Number of tall trees	Soil hardness		Number of holes	Canopy	Number of tall trees	Soil hardness		Number of holes	Canopy	Number of tall trees	Soil hardness	
Average		**0.68**					**0.67**					**0.67**					**0.87**				

4. CONCLUSION

We assessed the quality of forest ecosystem by using multiple SI models. Additionally, we indicated ways of improving the forest quality by altering the habitat conditions for endangered species.

However, in Japan, there are not many developed SI models, so we need to construct SI models for assessing forest ecosystem according to the situation. Also, since mountains in Japan consist of diverse forest types, how to assess these in detail is one of future tasks. In addition, it is required to improve the selection of indicator species for assessing the forest ecosystem, and consider the trade-off between habitat conditions for each species when the number of species increases, in question.

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